Institute for Public Policy Research

IPPR North

THE HYDROGEN POWERHOUSE?

DEMYSTIFYING THE NORTH'S HYDROGEN ECONOMY

Jonathan Webb, Joshua Emden and **Nick Gray**

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IPPR North
Suite 4.07
Blackfriars House
Parsonage
Manchester
M3 2JA
E: north@ippr.org
www.ippr.org/north

Registered charity no: 800065 (England and Wales), SC046557 (Scotland)

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ABOUT THE AUTHORS

Jonathan Webb was a senior research fellow at IPPR North at the time of writing.

Joshua Emden is a senior research fellow at IPPR.

Nick Gray was a research fellow at IPPR North at the time of writing.

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SUMMARY

The drive to net zero will require both fundamental changes in our behaviour and the development of new technologies that enable us to reduce emissions. One of the most promising technological developments that can help us transition to net zero is the production of hydrogen fuel. Unsurprisingly, the promise of hydrogen as an alternative fuel source to fossil fuels has attracted significant attention from policymakers and businesses.

Despite this growing interest in hydrogen, there is a need for greater clarity about the role hydrogen can play in a transition to net zero – not only from an environmental perspective but from an economic one. In the north of England, hydrogen has been presented as a key plank of future economic growth and prosperity that can help level up the North's industrial heartlands, while also delivering wider economic benefits through, for example, supporting R&D institutions to develop hydrogen technologies.

This report aims to identify the true potential of the UK's hydrogen economy, demystify the role that hydrogen will play in helping the UK reach net zero and evaluate the current state of play of hydrogen development in the North.

THE TYPE OF HYDROGEN MATTERS

- There are different types of hydrogen, each with a differing climate impact. Grey hydrogen has a comparable impact to fossil fuel use. Blue hydrogen can only be considered a clean alternative depending on the extent to which the emissions from its production are successfully captured. To be a viable low-carbon fuel, current capture rates for blue hydrogen would need to increase to 95 per cent of all emissions from the production process.
- Green hydrogen represents the only clear low-carbon fuel source as its production process uses renewable energy as opposed to fossil fuels. However, the extent to which it can provide a viable net zero fuel source is contingent on the UK massively scaling up the amount of renewable energy it currently produces. Without this renewable energy, large scale green hydrogen production will not be possible.

CURRENT UK GOVERNMENT POLICY REQUIRES A GREATER SENSE OF DIRECTION

- The UK government has laudable objectives when it comes to producing hydrogen. It currently aims to produce 10Gw of hydrogen fuel by 2030 (BEIS 2022a). However, despite an 'expectation' that 5Gw of this target will come from green hydrogen, it is not clear from current policy how this will be achieved or what the precise mix of different hydrogen fuel types should be in future. In the context of the differing climate impact of blue and green hydrogen at this moment in time, further clarity is important if this 10Gw objective is to be environmentally credible.
- At the same time, it remains unclear what role hydrogen will play in specific sectors of the economy. According to the CCC's Balanced Net Zero Pathway, hydrogen is likely play an important role in industrial decarbonisation and some aspects of heavy duty road transport but will be a much smaller role in heating and passenger transport. However, government policies supporting hydrogen are less clear and do not obviously align with this advice.

CLARIFYING WHERE HYDROGEN IS NEEDED

- For hydrogen to play a credible role in the UK's net zero transition, greater clarity is needed on where it is likely to be used. IPPR North's analysis suggest that hydrogen will play a pivotal role in supporting industrial decarbonisation. Recent analysis from the CCC also suggests that hydrogen power stations (converted from gas) could also play a small but important 'peaking' role in the UK's power system, although both the technology and scale of deployment is uncertain (CCC 2023). Our analysis suggests that while developing and operating hydrogen technologies will peak at a cost of approximately £3.5 billion a year.
- Hydrogen could also play an important role in supporting the decarbonisation of transport. Specifically, heavy goods vehicles.
- Neither the CCC's analysis nor IPPR's own analysis envisage a significant role for hydrogen in decarbonising heating in homes (Webb et al 2020), with the possible exception of homes near industrial clusters where hydrogen infrastructure may be more accessible.

HYDROGEN DEVELOPMENT IN THE NORTH

- Hydrogen development in the north of England is currently concentrated around key industrial clusters in Teesside, the Humber and Merseyside.
- The economic and proposed environmental benefits of the clusters are still uncertain. Net Zero Teesside, Zero Carbon Humber and HyNet in Merseyside all have significant ambition to deliver both large quantities of hydrogen, while also building the local net zero economy connected to each of the cluster's geography.
- A theme across the hydrogen clusters is a phased approach to hydrogen. This emphasises an intermediate role for blue hydrogen before scaling up the use of green hydrogen. While this approach makes sense given it is currently more feasible to produce blue hydrogen at scale, these clusters are likely to only have a long-term positive climate impact if they are predominantly producing green hydrogen by 2050. It remains far from certain that carbon capture rates for blue hydrogen will reach 95 per cent by 2050 and as such, only green hydrogen currently provides long-term certainty.

RECOMMENDATIONS TO DELIVER ON THE PROMISE OF HYDROGEN

- We recommend that the UK government works to provide a hydrogen plan that provides long-term certainty. This includes prioritising the expansion of green hydrogen production, ensuring that hydrogen production occurs in line with the sectors where it is needed and the introduction of a 'deep blue hydrogen' standard which requires all CCS technology to meet a minimum 95 per cent capture rate and issues severe penalties for methane leakages.
- While a 'clusters' approach to hydrogen production is logical, more can be done to support the UK's wider nascent hydrogen structures. This includes expanding the public investment available to support businesses and research institutions beyond hydrogen clusters, sector specific support to adopt hydrogen technologies and for the UK government to establish a new hydrogen strategy group who can work with and support its appointed 'Hydrogen Champion'.
- Support for the North's developing hydrogen economy should continue. Specifically, central government should continue to work with its research and local partners to develop concrete plans for hydrogen development at the local level. At the same time, UK government should also consider creating a new hydrogen acceleration forum to further drive innovation and hydrogen development in the North. This would help promote innovation and collaboration, as opposed to competition.

1. INTRODUCTION

Realising a net zero future will require fundamental changes across society and the economy. Alongside wider economic systems change and changing the behaviours of individuals, new technologies will play a crucial role in aiding the shift to a net zero transition. Perhaps one of the most promising technologies for aiding the shift to net zero is the production of hydrogen fuels.

Despite the increasing frequency with which hydrogen is referenced by policymakers, there remains significant question marks around the role it will likely play in transitioning the UK to net zero. Some of these question marks are theoretical, in terms of understanding the precise carbon reductions a shift to hydrogen fuels will achieve. Much of this is also practical, however. For example, the extent to which hydrogen can be developed and used is highly related to the development of other low carbon policies such as the expansion of renewable energy generation and the extent to which hydrogen is feasibly deployed across different sectors of the economy.

The environmental and economic case for providing this clarity is clear. As well as helping meet the UK's net zero ambition, hydrogen has also been cited as a key part of the North's levelling up, providing access to new economic opportunity, building on the North's industrial heritage and providing a new generation of workers with access to well-paid vocational jobs (HMG 2021a).

In the current context of the UK's interrelated energy crisis and cost-of-living crisis, the need to improve the UK's energy resilience has been thrust into the spotlight. Ramping up the amount of renewable energy the UK produces domestically and producing alternative clean fuels such as hydrogen will play a crucial part in both reducing our dependency on imported fossil fuels and providing energy security for the UK (Jung et al 2022).

This report provides an overview of the UK's emerging hydrogen economy. It provides an explainer on what hydrogen is, where it is likely to be used and the current state of play when it comes to hydrogen across the north of England. Through this research, we develop the policy case for providing further clarity on where hydrogen will be deployed and how from the UK government. In line with our analysis that suggests that the development of 'green' hydrogen remains most viable as a long-term solution to decarbonising the economy, our recommendations call for a greater focus on green hydrogen development both within existing industrial clusters in the North, as well as more broadly through the development of a wider hydrogen strategy that builds the broader R&D infrastructure needed to support the scaling of green hydrogen beyond the current clusters.

2.
A HYDROGEN EXPLAINER

This chapter explores what hydrogen is, how it is produced and the sectors where it will need to be used to reduce emissions. This chapter serves as a myth busting exercise.

WHAT IS HYDROGEN?

Hydrogen is a common chemical element, which frequently takes the form of a highly combustible gas. Hydrogen represents an alternative to carbon-based gases such as methane, which produce carbon dioxide when used as a fuel source.

While hydrogen is commonly presented as a clean fuel, the extent to which hydrogen can in fact be termed as such depends on how it is produced. Hydrogen produced from natural gases (such as methane) is often termed 'grey hydrogen'. This type of hydrogen cannot be considered clean as the gases used in its production are not captured or stored and subsequently, are released as CO2. When the excess carbon is captured from this process and stored through a process of carbon capture and storage (CCS), the type of hydrogen produced is called blue hydrogen. While carbon is captured, this method is still reliant on a continued extraction and use of fossil fuels. In addition, the extent to which this method is truly 'low-carbon' and clean depends on the effectiveness of carbon capture and storage (CCS) technology to capture and store the carbon emitted through its production. Concerningly, a recent study suggested that the prevalence of methane leaks in the lifecycle of blue hydrogen production could lead to 20 per cent more emissions than simply burning natural gas, depending on the effectiveness of CCS technology (Howarth et al 2021).

Even in a best-case scenario, current CCS technology would be unable to capture all the emissions generated through blue hydrogen production. Indeed, current industrial processes such as steam methane reforming result in only 60 per cent of emissions being captured, producing hydrogen as a by-product (CCC 2018). Currently, the CCC's role for blue hydrogen assumes that a 95 per cent carbon capture rate is achieved if blue hydrogen is to be a credible part of decarbonising the UK's economy by 2050 (CCC 2020a).

The final type of hydrogen, green hydrogen, is produced via electrolysis, whereby water is broken into its component elements of hydrogen and oxygen using electricity. Unlike grey or blue hydrogen production methods, it is not dependent on the use of natural gases.

TABLE 2.1: OVERVIEW OF HYDROGEN TYPES, PRODUCTION PROCESSES AND PROPOSED CARBON IMPACTS

Type of hydrogen	Production method	Carbon impacts
Grey hydrogen	High-temperature steam (700°C–1,000°C) is used to produce hydrogen from a methane source, such as natural gas. The process produces carbon which is not captured.	High - comparable to direct use of natural gas.
Blue hydrogen	Same process as grey hydrogen but produced carbon is captured and stored.	Direct carbon impact the subject to much scientific debate. In any case, blue hydrogen prolongs dependency on natural gas and can cause methane leakage upstream via the production process.
Green hydrogen	Green hydrogen is made by using a process called electrolysis to split water into hydrogen and oxygen. If that process is powered by a renewable energy source, such as wind or solar power, then the hydrogen is referred to as being green.	No direct carbon impact and use of renewable energy avoids carbon dependency/ natural gas production.

Source: Brunel (2021)

In this context, only green hydrogen can be deemed a completely clean energy source both in theory and in practice. This is because it uses renewable energy to convert water into hydrogen fuel via electrolysis. As the rest of this chapter highlights however, there remain significant obstacles to scaling up the UK's green hydrogen production.

CHALLENGES IN PRODUCING GREEN HYDROGEN

While green hydrogen is clearly preferable from a climate perspective, there are two primary challenges that hold back the UK's development of green hydrogen. First, producing green hydrogen requires significant quantities of renewable electricity. There remains a significant challenge in ramping up the UK's renewable energy generation to make green hydrogen at scale a realistic prospect (Spyroudi et al 2021). While the UK is making substantial progress in decarbonising the electricity grid, to produce green hydrogen at scale would require deployment over and above the already stretching deployment rate of renewable generation (CCC 2022) This challenge is not explicitly acknowledged in the UK government's *Hydrogen Strategy,* which focuses both on blue and green hydrogen production in its vision for future hydrogen use (HMG 2021a).

Second, green hydrogen currently costs significantly more to produce than grey or blue hydrogen (CCC 2020a). While this is currently the case, these costs can be expected to fall over time as technologies scale up (ibid). As the Department for Business, Energy and Industrial Strategy's own assessment in 2021 concludes: 'over time and depending on fuel price assumptions, different electrolysis configurations are coming down in costs and in some cases become cost competitive with CCUS-enabled methane reformation technologies' (BEIS 2021a). In effect, over time there is significant scope for green hydrogen costs to reach parity with blue hydrogen costs. This is particularly true given the current surge in international gas prices, on which the blue hydrogen manufacturing process heavily depends. In the long run, this creates a poor climate and economic case for investing in blue hydrogen as opposed to prioritising the scaling up and adaption of green hydrogen which is itself a much cleaner fuel source.

3.
RHETORIC AND REALITY

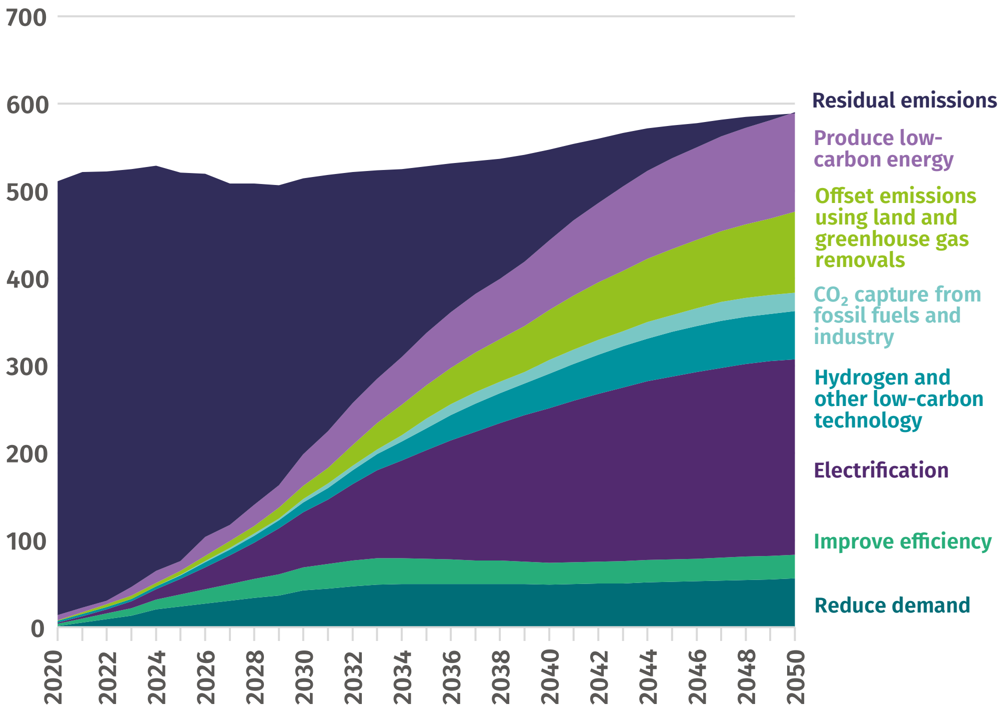
HYDROGEN, A PANACEA FOR THE UK'S ENERGY TRANSITION?

There remains uncertainty about the extent to which hydrogen will feature in the UK's net zero future. The CCC (2020a) anticipates in their Balanced Net Zero Pathway scenario that by 2050, hydrogen will represent a comparatively small part of the decarbonisation picture when compared to electrification (ibid). This scenario excludes the use of hydrogen in some areas where it might eventually be required. For example, in the production of low-carbon steel (Webb 2021).

Green hydrogen remains the only proven long-term hydrogen solution that we know for certain will reduce overall emissions. However, its role in helping the UK reach net zero is less significant than widespread electrification. Only in a scenario where the CCC predicts low levels of individual behaviour change and innovation would hydrogen play a more significant role (CCC 2020a). In this case, the majority of hydrogen used would be blue, not green. As a result, from an emissions perspective, this scenario is less preferable given that blue hydrogen may have a climate impact.

FIGURE 3.1: THE ROLE OF HYDROGEN IN DECARBONISING THE UK

Hydrogen will play a comparatively less important role overall than other technologies, such as electrification and strategies such as offsetting



Source: CCC (2021)

Producing green hydrogen at scale requires significantly increasing the amount of renewable energy generation potential in the UK. Countries where green hydrogen production is beginning to develop at scale can produce large quantities of renewable energy and energy prices are comparatively lower. For example, in Sweden, extensive hydropower and comparatively lower energy costs have supported the development of green hydrogen production (Webb 2021).

Overall, to date, only green hydrogen has a proven long-term positive climate impact. The eventual climate impact of blue hydrogen remains uncertain.. Despite this, the prevalent narrative around hydrogen presents an overly optimistic picture of its widespread use, while simultaneously remaining vague about the extent to which hydrogen is a credible solution for decarbonisation across a range of sectors.

THE GOVERNMENT'S HYDROGEN POLICY

The UK government has referenced hydrogen in several key reports. These include its industrial strategy, net zero strategy and hydrogen strategy. Across these documents, it envisages there being a clear role for hydrogen. For example, the net zero strategy outlines the government's ambition to produce 10Gw of low-carbon hydrogen capacity by 2030 (BEIS 2022a) and to implement its £240 million Net Zero Hydrogen Fund to accelerate the development of hydrogen (HMG 2021b). This commitment was originally made in the government's *Ten Point Plan for a green industrial revolution* (HMG 2020). The government's *Build Back Better: our plan for growth* points to the potential job generation of the hydrogen economy, highlighting its ambition to create 60,000 jobs in the offshore wind sector, 50,000 jobs in carbon capture and storage and 8,000 jobs in hydrogen production (HMT 2021).

Alongside these overarching plans, the UK government has also referenced the specific role that hydrogen can pay in decarbonising key sectors. For example, its Industrial Decarbonisation Strategy explicitly references a role for hydrogen to decarbonise key industrial processes (BEIS 2021b). It also acknowledges how existing industrial cluster infrastructure can be used to support the development of new hydrogen technologies.

Despite the government's clear ambition to develop the hydrogen economy, these flagship policy documents do not substantiate further on how or what type of hydrogen will be developed. While the newly created DESNZ has recently indicated it expects at least 5Gw of its target to come from green hydrogen, it has not set out plans for how this will be achieved and so the overall future mix remains unclear (NAO 2023). This is a crucial omission in that the type of hydrogen prioritised will have a significant impact on both job creation and the climate impacts of the net zero transition. The need to develop CCS infrastructure and facilities will likely support further job creation. However, this assumes the substantial development of blue, as opposed to green hydrogen, which as previously noted could have a worse climate impact. On the other hand, the development of green hydrogen will necessitate the massive expansion of renewable energy generation, while reducing the need for CCS infrastructure. The government has also not set out the funding mechanisms for how it will achieve its 10Gw target either. Therefore, the precise economic and job benefits of hydrogen are difficult to quantify without mapping out in detail the type of hydrogen generation being prioritised, where, and in which sectors of the economy. The subsequent chapters of this report do this in further detail for the north of England.

The UK government's *Hydrogen Strategy* acknowledges that the majority of hydrogen produced in the UK to date is not green hydrogen and that globally, most hydrogen is produced from fossil fuels without suitable CCS technology to capture residual emissions (HMG 2021a). The strategy further outlines the government's ambition to deploy blue hydrogen projects by the mid 2020s, as well as a long-term ambition to grow low carbon hydrogen production by the end of the 2020s (ibid). However, it is not explicitly clear what the precise mix of blue and green hydrogen would be in this long-term ambition. The absence of this important detail is critical given the chosen end goal and precise mix of hydrogen technologies the UK wishes to develop will have differing job and environmental impacts depending on the extent to which green or blue hydrogen features in its final pathway to net zero.

In sum, the UK government has made a clear commitment to hydrogen and believes it is a fuel source that will play an important role in helping the UK shift to net zero. However, key policies to support the development of the hydrogen industry are still in their early stages and the development of hydrogen remains embryonic. The next chapter seeks to substantiate potential for the UK's hydrogen economy further by understanding where it is likely to be used and the policies needed to realise its use across those sectors.

4.
WHERE IS HYDROGEN NEEDED?

Hydrogen is often touted as a cure-all solution to the UK's net zero transition. However, while hydrogen will have an important role to play in some sectors, particularly for energy-intensive industries, its potential use across other sectors of the economy is likely to be overstated.

To better understand and map where hydrogen will be needed, the following sections outline the key sectors of the economy where hydrogen will have to play a key role and those sectors where it is unlikely to play a significant role.

INDUSTRIAL DECARBONISATION – A KEY ROLE FOR HYDROGEN

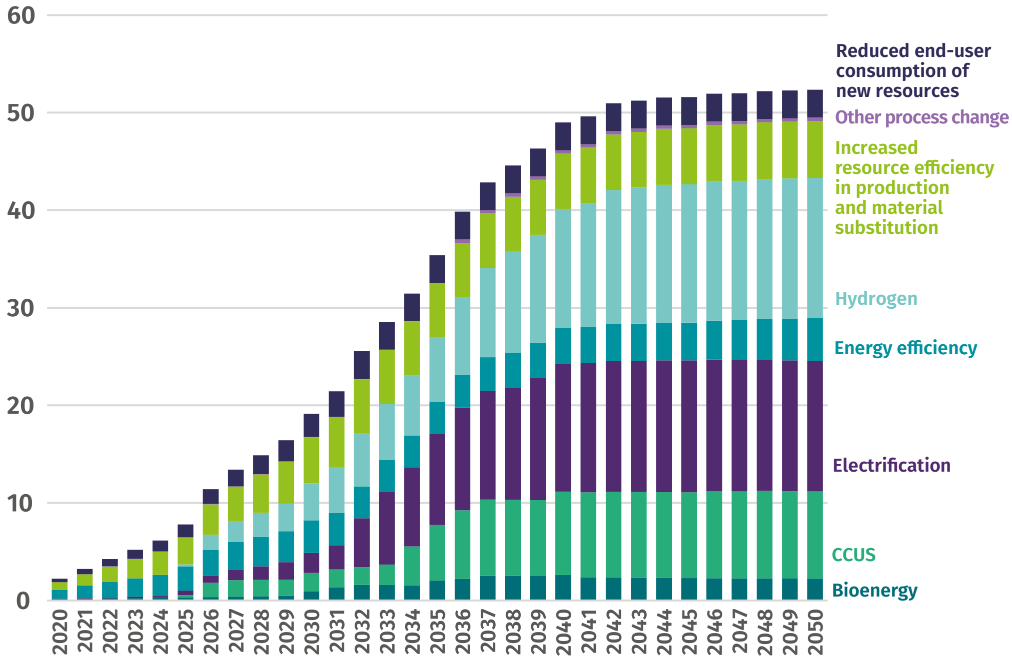
One of the main areas where hydrogen will play a pivotal role in the UK's transition to net zero is the manufacturing and construction sector. In this sector, hydrogen can play a key role in decarbonising specific industries such as steel and as a fuel source for off-road mobile machinery (CCC 2020b).

The extent to which hydrogen is deployed in this sector will be contingent on a range of factors, including the extent to which hydrogen infrastructure, both in terms of production and transportation, is scaled up, as well as decisions around the best technology for specific manufacturing and construction sub-sectors. An area where IPPR North has previously identified a clear role for hydrogen is in decarbonising the UK's steel industry. In this industry, hydrogen represents the most valid pathway to decarbonisation due to: its lower long-term emissions when compared to a CCS pathway to decarbonisation, long-term cost effectiveness and that the current configuration of UK steel and hydrogen innovation clusters would allow the UK to begin trialling this form of hydrogen production imminently (Webb 2021).

Other industrial sectors where hydrogen is likely to play a role includes the production of lime and ceramics, refining of chemicals and heating in other industrial processes (Element Energy 2020). In these cases, current technologies, not least gas boilers, could be replaced by hydrogen equivalent technologies. In effect, hydrogen plays a key role in these sectors both as a fuel switching option and in the case of sectors like steel, as a process switching option (ibid). It is worth noting that alongside hydrogen, electrification will play a major role in decarbonising UK industry (CCC 2020b). With the benefits of green hydrogen in mind, massively ramping up the UK's renewable energy generation potential will be necessary to enable both wider electrification and the development of hydrogen as a credible and clean fuel for industry as part of the UK's net zero strategy.

FIGURE 4.1: UNDER A 'BALANCED NET ZERO PATHWAY'[1] SCENARIO, HYDROGEN PLAYS A ROLE IN DECARBONISING INDUSTRY, ALTHOUGH IT DOES NOT REPRESENT THE MOST SIGNIFICANT ABATEMENT TECHNOLOGY

Role of hydrogen in decarbonising industry alongside other technologies in a 'Balanced Net Zero Pathway Scenario'



Source: CCC (2021)

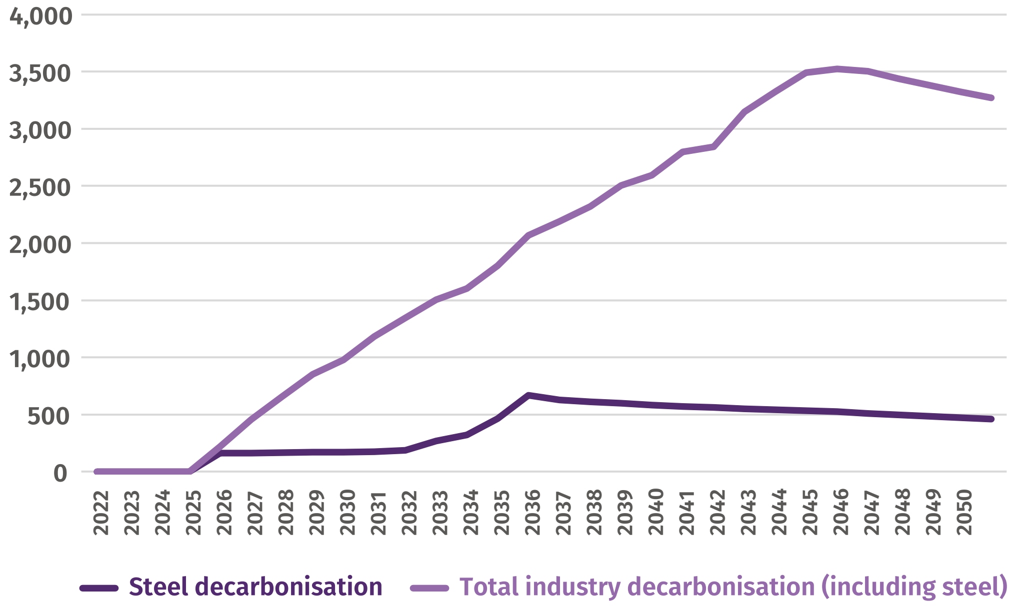
In terms of the proposed cost of deploying hydrogen to decarbonise the UK's heavy industry, IPPR North has developed an estimate of the cost differential for this. The cost differential shows the cost difference between deploying hydrogen to decarbonise industry and that of the baseline cost, which assumes no action is taken to decarbonise industry. These costs include both operational costs and capital expenditure costs that would also exist in a scenario where no decarbonisation occurs given the ongoing costs of carrying out industrial activity. This cost differential suggests that deploying hydrogen to decarbonise UK industry will peak at approximately £3.5 billion a year.[2] These deployment costs should be considered alongside the estimates from the UK government that suggest the UK's hydrogen economy could be worth £13 billion by 2050 (HMG 2021a).

1 Further information on these scenarios can be found in the CCC (2021) sixth carbon budget report. In short, A Balanced Net Zero Pathway represent a recommended scenario that reaches Net Zero by 2050. It is designed to drive progress through the 2020s, while creating options in a way that seeks to keep decarbonisation options open.

2 This cost doesn't include the total cost differential for decarbonising UK industry. It only includes the hydrogen element. Wider costs will be incurred through other abatement solutions such as electrification. These are not captured here as the focus of this report is on the deployment of hydrogen.

FIGURE 4.2: THE ESTIMATED COST OF DEPLOYING HYDROGEN FOR INDUSTRIAL DECARBONISATION PEAKS AT AROUND £3.5 BILLION IN THE 2040S

Cost differential of deploying hydrogen for industrial decarbonisation processes over and above current costs of taking no action to decarbonise industry[3]



Source: IPPR North analysis using underlying data from Element Energy (2020)

PROVIDING FLEXIBILITY TO THE POWER SECTOR

Recent analysis from the CCC also suggests that 'hydrogen power stations' could also play a small but important 'peaking' role in the UK's power system, providing back up power when the wind or solar power are not generating electricity. These power stations could come from converting existing gas power stations and in its modelling the CCC estimates that between 8–16Gw of hydrogen-fired turbines could be built, amount to between 23–46 per cent of current gas capacity on the system (CCC 2023). However, the CCC also notes that the scale of hydrogen power stations is highly uncertain since gas power stations fitted with carbon capture and storage (CCS) could play a similar role. Furthermore, neither technology has been built at commercial scale yet in the UK and no gas power stations have yet undergone any conversion or retrofitting.

PROSPECTIVE ROLE IN TRANSPORT

Both the CCC and National Grid ESO only see hydrogen playing a relatively limited role in transport. In total the CCC sets how energy demand from surface transport will require around 120TWh to come from electricity in 2050 compared to only 12TWh from hydrogen (CCC 2020). This hydrogen demand predominantly comes from heavy goods vehicles (around 11TWh), where hydrogen may be more appropriate due to longer average journey miles than cars, with a fraction of hydrogen demand coming from buses and coaches (around 1TWh). In the case of cars, the rollout of electric vehicles alongside some investment in battery manufacturing is already well underway and hydrogen fuel cell infrastructure is far less mature in the UK.

3 Our modelling follows the Net Zero Balanced Pathway. However, it differs in that it assumes a significant role for hydrogen in decarbonising the steel industry. The reasons for deploying hydrogen to achieve this have been made in previous IPPR North research (Webb 2021).

HYDROGEN IS LIKELY TO PLAY A MUCH SMALLER ROLE IN HOME HEATING

Hydrogen is likely to play a much smaller role in home heating for several reasons. First, as discussed above, rolling out the infrastructure to produced hydrogen would either be slow, not particularly low-carbon, or both. The one exception may be homes near industrial clusters where hydrogen infrastructure will already be in place and shorter transportation distance will mean developing local hydrogen networks may be more feasible. By contrast, electrified heating technologies like heat pumps are already commercially available and provide more immediate emissions reductions than the hydrogen manufacturing process. For example, in the case of blue hydrogen the CCS technology deployed still needs to substantially improve its CO2 capture rate (to at least 90 per cent) before it is considered a viable option within net zero scenarios (2018a; CCC 2019a).

In addition, a hydrogen-dominant economy where hydrogen boilers play a substantial role in heat decarbonisation would require an estimated 60 per cent increase in natural gas imports to produce blue hydrogen at a time when international gas prices are soaring. On top of paying back infrastructure costs, this would make hydrogen boilers significantly more expensive to run than heat pumps. Lastly, it is important to consider the ethics of increasing gas imports, as this will increase emissions associated with natural gas extraction abroad but will not be counted in the UK's territorial net-zero target.

In a scenario where new technologies such as Auto Thermal Reformers replace the SMR process of producing hydrogen, both upfront costs and CO2 capture rates can be substantially improved (Strbac et al 2018). However, currently this technology is not mature and consequently not considered by the CCC. Furthermore, while green hydrogen is envisaged as the main method of hydrogen production by 2050, if hydrogen boilers were to become the dominant home heating technology, the increase in demand would require both high upfront costs and an unmanageably high annual rate of deployment of new renewable energy projects to supply electricity for the electrolysis process (CCC 2019a).

5.
THE HYDROGEN ECONOMY IN THE NORTH

AN OVERVIEW OF HYDROGEN DEVELOPMENT IN THE NORTH

Central to the UK government's net zero and an important part of its levelling up strategy is the development and acceleration of hydrogen production in the north of England. While current industrial policy has emphasised the importance of the North's emerging hydrogen economy, the North also has a rich industrial heritage. This current focus coincides with a shift away from the previous National Industrial (HMG 2017).

From a regional policy perspective, clean growth, including efforts to develop the hydrogen economy, is posited as an important component in economic levelling up and, as a part of the government's current industrial strategy (HMT 2021). Levelling up and current industrial policy means there is ongoing policy interest in facilitating growth through new industries like hydrogen, as well as fostering innovation and demand for higher level skills in the UK's poorer regions.

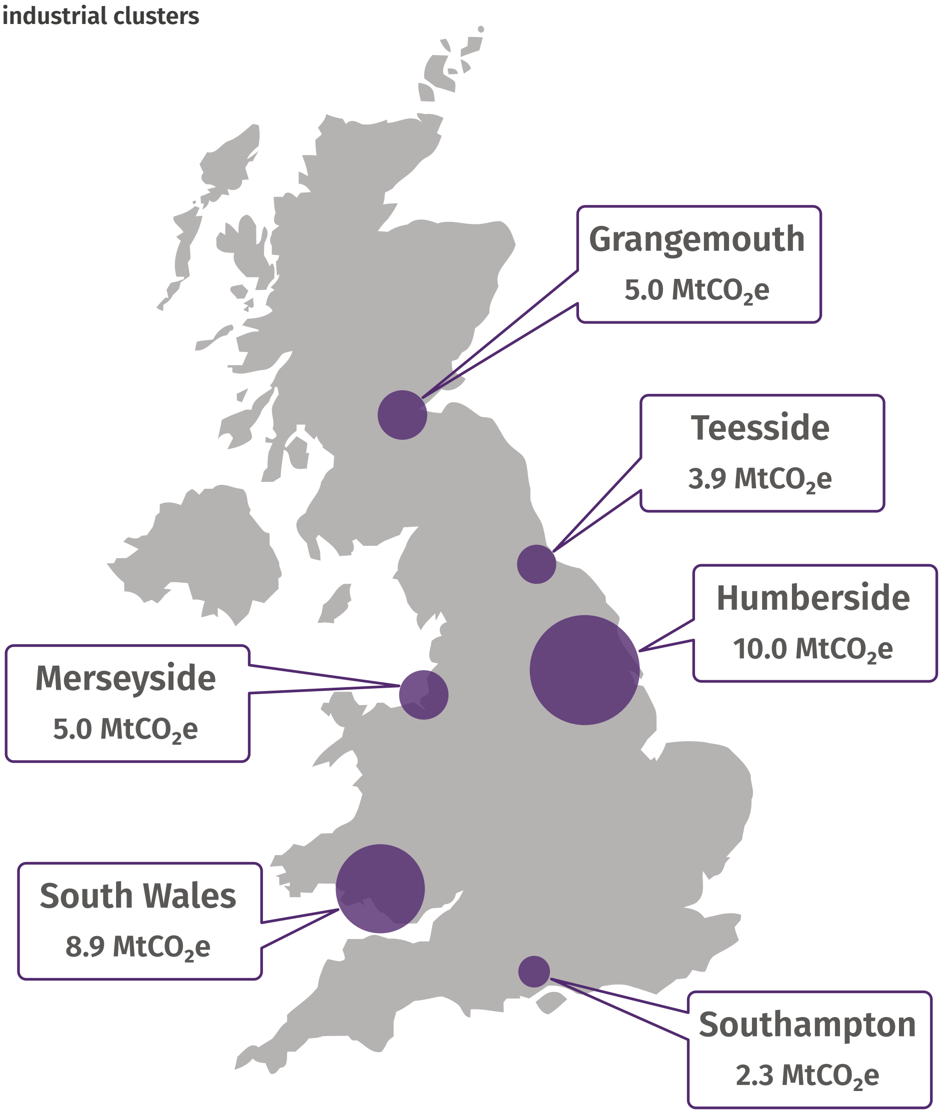
In addition to this policy, the energy sector is one of the North's major assets, with northern regions producing 51 per cent of all of England's renewable energy (Webb et al 2022). Up to 46,000 jobs could be created by 2030 in the North's energy sector (Emden and Murphy 2018). However, the benefit of these new jobs will only be felt if workers are supported to take up new jobs in the net zero energy sector. These low-carbon energy jobs will be crucial for supporting the development of new fuels like hydrogen, which, as chapter 3 noted, will only be possible with a huge expansion in renewable energy generation. Across the north of England there are potentially 28,000 job losses in the coal, oil and gas industries by 2030, plus extensive job losses in high-carbon energy intensive industries (ibid). In this context, it is vital to consider how a just transition can be achieved to ensure that carbon intensive industry workers can transition into low-carbon jobs.

AN ANALYSIS OF PROPOSED HYDROGEN CLUSTERS IN THE NORTH

The UK government is attempting to encourage the development of zero carbon hubs (including hydrogen) in the UK's largest and most carbon intensive industrial clusters. Three of these are located in the north of England (BEIS no date). The northern clusters are on the Humber, Tees Valley and in the North West, particularly Merseyside, where the cluster also crosses the border into North Wales. As well as being carbon intensive, these industrial clusters are already located near existing oil and gas facilities necessary to produce grey hydrogen. There has also been recent investment in carbon capture technology that would allow the conversion of grey into blue hydrogen (Edwards et al 2021). As a result, much of the proposed private investment in and development of hydrogen technology at these sites is from large oil and gas companies seeking to repurpose and potentially decarbonise their existing infrastructure.

FIGURE 5.1: AN OVERVIEW OF THE UK'S INDUSTRIAL CLUSTERS

Hydrogen development in the north of England is concentrated around its three industrial clusters



Source: BEIS (2021b)

The UK government has sought to support the public and private sector to develop net zero projects . It has also provided limited direct public funding through for example, the Low Carbon Hydrogen Supply Competition (BEIS 2022b). The UK Research Innovation Industrial decarbonisation challenge fund has also funded 'roadmap' research in each of the three northern clusters and continues to support R&D in relation to hydrogen (UKRI 2022).

While this report predominantly concentrates on the three northern clusters, it is important to note not all of the activity to develop hyrodgen in the north is happening solely in these clusters. This includes research and development activities such as the Hydrogen Transportation Network led by Durham University (Net Zero Research Network no date) or ITM Power's electrolyser manufacturing operation in Sheffield (ITM Power no date) While a significant proportion of funding is put into growing these clusters and decarbonising existing industries within them, there is a wider ecosystem of research institutions and businesses supporting the development of the North's hydrogen potential.

CASE STUDY: NET ZERO TEESSIDE

Local context

Tees Valley has many well documented long term socio-economic challenges that developed throughout 20th century and worsened in the wake of the deindustrialisation of the 1970s and 1980s (Evenhuis 2018). In recent decades, this has been exacerbated by the closure of Redcar steel works (ibid). Prior to the Covid-19 crisis, economic productivity in Tees Valley and Durham was 65 per cent of the UK average (Eurostat 2022) while the unemployment rate in Tees Valley was 6.4 per cent, low by its own historical standards but still well above the UK rate (3.9 per cent) (ONS 2022a). The region has a relatively low concentration of people in higher skilled and higher paid jobs and is more reliant that many places on jobs in elementary occupations, leisure and retail (ONS 2022b).

Health and disability are significant barriers to work and rates of long-term sickness among the economically inactive are high. Parts of Tees Valley have very high levels of deprivation, and this is particularly clear in Middlesbrough. For example, the 2019 English Indices of multiple deprivation demonstrate that the local authority is, on many measures, the most deprived in England and that deprivation here is especially concentrated. However, underlying social and economy challenges have worsened over the past decade (Marmott et al 2020).

The region's challenges are familiar but there are also opportunities and strengths in the Tees Valley (Heseltine 2016). In recent years, the region has built a comparatively stable and effective regional governance partnership and the metro mayor and combined authority have a range of relatively constrained but growing devolved powers and resources. Economically, Tees Valley firms remain competitive in, for example, advanced manufacturing and the chemical and processing industries.

Hydrogen production in Teesside

Teesside already produces much of the UK's blue Hydrogen as an industrial by-product. The presence of a Tees Valley Hydrogen economy is built on the legacy of Imperial Chemicals Industries (ICI) including a BOC production plant (relatively small scale in the context of Net Zero Teesside ambitions) and a CF Fertilizers operation that produced hydrogen from natural gas as a by-product of fertilizer production.

Net Zero Teesside aims to facilitate a cluster of low carbon manufacturing business across several sites on the Tees, some of which are covered by a freeport offering tax incentives on capital investments and new jobs. The cluster is built around carbon capture and storage from a proposed gas fired power station, producing blue hydrogen with carbon captured, transported, and stored in the Endurance saline aquifer beneath the North Sea. Tees Valley is also the site of a relatively small scale 'Hydrogen Transport Hub' to trial Hydrogen transport technology (seed funded with £3 million and due to be operational by 2025) (DfT 2021) and some private sector exploration of green hydrogen production including BP's HyGreen project (BP 2021).

In August 2021 Net Zero Teesside Power Limited formally submitted a Development Consent Order to the planning inspectorate with the expectation that the secretary of state will grant consent to being work of the onshore element of NZT Power, including the new gas fired power station.

Tees Valley Combined Authority and the Tees Valley Mayor have been prominent in the development of and advocacy for the project including the freeport, covering Teesworks, the proposed site for the NZT power station. In practice, the development sites and projects are driven by private sector companies, particularly large energy firms seeking to turn their existing physical infrastructure to lower carbon production.

NZT Power is a collaboration between two big energy companies, the UK's BP, and Equinor from Norway. So far, there are plans for NZT Power to feed three proposed blue hydrogen production facilities, one from global energy firm Linde BOC, another run by Kellas, and one by NZT Power partner BP. Alongside this, the carbon transport and storage facility is run by the Northern Endurance Partnership of UK multinationals National Grid and Shell alongside Equinor or Norway and France's Total.

Key players and sites

- Net Zero Teesside Power
- Three Blue hydrogen facilities drawing on NZT Power
- Endurance Aquifer (it is planned that the endurance facility will service all the East Coast Cluster of carbon capture and storage cluster including Net Zero Teesside and Net Zero Humber)

Economic and environmental impact

The Teesworks site (the planned site of NZT Power) is still under remediation at the time of writing, and this is likely to take significant time. An economic impact assessment by consultants Vivid Economic (2020a) assumes the construction phase will last until 2028. The report claims that Net Zero Teesside could support 4,500 direct jobs during the construction phase and 900 direct jobs during the operational phase to 2050 (ibid). In addition, the report claims that, during the construction phase, NZT could also support 13,500 indirect and induced jobs annually from increased spending in the supply chain and the regional and national economy (ibid). Over the project period, the assessment suggests that Net Zero Teesside could account for £4.5 billion of GVA, with a most of this concentrated in the Teesside area.

The Vivid Economics report is careful to clarify that the employment numbers are *jobs supported*, and this would include the protection/transition of jobs in, or dependent upon, existing carbon intensive industries. TVCA are currently looking to retrain and reskill local residents so they can take up new job opportunities and there currently a Clean Energy Education Hub is being built to support this (Alexander 2022). In this context, the Vivid Economics report claims that that Net Zero Teesside could safeguard 35 per cent to 70 per cent of *existing* manufacturing jobs in Tees Valley while *helping* to enable 7,000 *potential* jobs identified in the South Tees Development Corporation master plan (TVCA 2019).

Similar caveats should apply to projections of the project's potential economic growth (GVA) contribution. These caveats on the posited economic gains reflect not only the inevitable uncertainty of economic projections around programmes and projects that are still in development, but also the nature of the project and the key players. That is, existing large energy firms seeking to repurpose their infrastructure (and jobs).

In addition, the Vivid Economics report reflects other regional assessments on the weakness in the Tees Valley labour market (TVCA 2021a), including skill shortages such as an existing shortfall in the availability of construction workers that is likely to widen if central government increases capital spending in line with projections (OBR 2022). This is likely to require a continued focus on relevant skills and recruitment, including working with local education providers and ensuring that existing skilled workers are able to transition into emerging roles.

Tees Valley Combined Authority has consistently championed hydrogen power as a regional economic strength and a potential contributor to UK net zero targets. The Combined Authority sees this as an innovation led agenda and highlights the Industrial Decarbonisation and Hydrogen Innovation Centre collaboration between TWI and Teesside University, alongside other regional innovation centres the Centre

For Process Innovation catapult and the independent Materials Processing Institute. At the same time, the combined authority highlights the relatively low levels of public and private research and development spending in Tees Valley and the wider region (TVCA 2021b). In terms of direct environmental impact, Tees Valley Combined Authority suggests that net zero Teesside will capture 6 megatons of carbon dioxide each year, the equivalent of the annual energy use of more than 2 million homes, along with producing 1.8Gw of zero-carbon power (ibid).

Conclusions

Overall, it remains difficult to assess the prospective impact of hydrogen development on Teesside. So far, it seems that the focus has predominantly been on developing the region's endogenous potential to produce blue hydrogen. Much of the current plans proceeding at pace are contingent on the speed at which the current Teesworks site is remediated and repurposed for the development of hydrogen production. While there are also significant efforts to produce renewable energy within proximity to Teesside which could be used to develop green hydrogen,[4] this appears to be a much smaller focus when compared to current efforts to scale up blue hydrogen production and plan for the associated CCS infrastructure.

Regardless of the current scale of the development, Teesside will need to play a crucial role if the UK is going to realise its hydrogen future. As a result, to ensure its sustainable and long-term economic and environmental impacts, further development of its green hydrogen potential will likely be needed.

CASE STUDY: ZERO CARBON HUMBER

Overview of project

As with Tees Valley, there are long term structural weakness in the regional economy in the areas surrounding the Humber. Prior to the Covid-19 pandemic, economic productivity in the wider East Yorkshire North Lincolnshire area was 77.7 per cent of the UK average and the unemployment rate in Hull and East Riding was 5.3 per cent above the national rate of 3.9 per cent (ONS 2022). Again, like Tees Valley, the region has a relatively low concentration of people in higher skilled and higher paid jobs and is more reliant that many places on jobs in elementary occupations Despite the challenges in the region, there are also perceived opportunities around, for example, manufacturing, construction and the port (HEYLEP 2022).

Humber Local Enterprise Partnership stopped operating in in 2021 with local economic strategy now the responsibility of Hull and East Yorkshire LEP on the north of the Humber and Greater Lincolnshire LEP in the south. While Zero Carbon Humber spans both areas, many of the significant hydrogen projects discussed in this report are in Hull and East Yorkshire where the LEP has identified low carbon as a regional sectoral strength. Within this, the LEP argues that region's potential to produce green and blue hydrogen could be a stimulus for regional innovation and piloting the wider deployment of hydrogen technologies (HEYLP 2022).

Zero Carbon Humber plans a mix of blue and green hydrogen schemes with the most ambitious being Gigastack, a project to produce green hydrogen at scale using renewable electricity from the planned wind farm at Dogger Bank and self-described as "the UK's flagship renewable Hydrogen project" (Gigastack 2022). Elsewhere, the EU Oyster consortium part funded by UE Horizon 2020 money also aims to produce green hydrogen using offshore wind generated electricity (Oyster Project no date). In addition, there are two proposed carbon capture and storage blue hydrogen projects run by Drax and Equinor (Equinor 2022) (H2H Saltend) with plans to store the captured carbon in the Norther Endurance aquifer (see Tees Valley. Most of the Humber projects are at an early stage.

4 For example, the HyGreen Teeside project which aims to produce 60Mwe of capacity by 2025 if approved.

Gigastack is a consortium of ITM power, a relatively small and new UK company, with larger partners Orsted of Denmark, Phillips 66 and Element Energy (part of ERM energy, in turn owned by Shell). Gigastack received UK government support for its phase one feasibility study (Gigastack 2020) and then in November 2021 published a report on its phase two preparation work including trials of the production equipment and preparation for its manufacture. A final investment decision is scheduled for 2023, “subject to a supportive policy environment” (Gigastack 2021).

The EU Oyster consortium again includes Orsted and Element Energy together with Seimans Gamesa from Germany. The project is supported by the EU 2020 programme and has a test facility in Grimsby (Oyster Project no date).

A consortium led by Drax with Equinor and National Grid proposes to produced blue hydrogen – this is still at the memorandum of understanding stage. H2H Saltend is an Equinor project to produce blue hydrogen. It claims to be the largest project of its kind in the word and aims to be operational by 2026, and producing hydrogen at scale by 2020 (Equinor 2022). Public consultation was due to be completed by May 2022 with site selection to follow. Dogger Bank windfarm itself is led by Equinor with another multinational, SSE energy. Construction has begun but is at an early stage.

Key players and sites

Plans are at the development and pre development order consultation stage, but significant potential projects are:

- Gigastack
- Oyster consortium
- H2H Saltend
- Drax
- Dogger Bank offshore windfarm

Economic and environmental impact

While Net Zero Humber is at a relatively early stage of development, a report by Vivid Economics commissioned by Drax, suggests that hydrogen technologies (including CCS) in the Humber area could support 16,000 direct jobs and £1.2 billion in direct GVA annually on average during the construction phase from 2024 to 2031 then up to 3,100 direct jobs on average in the operations maintenance of between 2032 and 2050 (Vivid Economics 2020b). In addition, the consultancy report claims that the Hydrogen and CCS could support 7,100 indirect and 10,900 induced jobs during the construction phase as well as £450 million in indirect and £580 million in induced GVA, annually, on average then 9,800 indirect and 17,200 induced jobs, as well as £840 million in indirect and £920 million in induced GVA, annually, during the operational phase from 2032 to 2050 (ibid). Again, it is important to emphasise, as with the Net Zero Teesside report, that this is based on early modelling and that these are direct jobs *supported* and may be displaced/transferred from other, carbon intensive, activities.

As with Tees Valley, regional policy reports and commissioned research identify a potential skills gap in sectors likely to be vital to Net Zero Humber, including construction and engineering. Citing the government Working Futures model (WIER 2021), the report argues that key manufacturing sectors – electricity and gas, engineering and construction – in Yorkshire and the Humber will require higher qualifications than currently available, potentially risking the decarbonisation of the region and the wider net zero target.

Conclusions

As with the development of hydrogen on Teesside, it is difficult to predict the precise economic and environmental impact that hydrogen production will have on the Humber. As with Teesside, there is a strong focus on blue hydrogen production, although key actors in the region appear to be actively exploring how the huge renewable energy generation potential of Dogger Bank can be maximised to develop green hydrogen.

In line with Teesside, if current plans come to fruition, it is likely that the Humber will, from the 2030s, host a mix of blue and green hydrogen development. The extent to which green hydrogen will be developed at scale is largely intertwined with the construction and expansion of Dogger Bank. In contrast, the development of blue hydrogen will be contingent on the construction of large CCS capacity of the Humber in the next few years.

The economic impact of the plans on the Humber remains difficult to quantify. It is highly likely that the hydrogen industry will support job employment into new industries. However, the extent to which local people find employment in these new jobs will depend on ensuring that the local skills system works to connect these new opportunities with current education and skills provision.

CASE STUDY: HYNET

Overview of project

HyNet is potentially the largest of the three broad projects discussed here, with a geography spanning the Mersey Dee Alliance area (MDA no date) covering Cheshire, Liverpool City Region and into North Wales, although the key Stanlow plant is at Elsmere Pore in Cheshire. Much of the Mersey Dee area experiences many of the economic challenges facing Tees Valley and Humber/Hull and East Yorkshire, although the Cheshire economy (core to Hynet) performs strongly with pre-covid GVA per-capita 20 per cent higher than the UK average with a large manufacturing and professional services base (Hildreth 2021), and regional policy makers identifying life sciences and logistics as potential growth sectors (CWLEP 2019).

Hynet is the flagship project in North West England (and North Wales) an ambitious assembly of large scale Hydrogen and capture and storage scheme. In the long term, there are plans for several facilities. Currently, the overall project is still the pre-Development Consent Order consultation phase, with a focus on an initial blue hydrogen production plant and the route for the pipeline needed to transport the captured carbon to storage under Liverpool Bay (HyNet 2022). Plans for the distribution network and other projects are to be dealt with separately.

As with the Net Zero Teesside, the initial production facility based at the Stanlow refinery at Ellesmere Port would be gas powered with the carbon captured, transported and stored undersea off the North West Coast. Stanlow and the carbon capture facility form the core of the project although, much of the policy and commercial literature in the region assumes this will be followed additional blue hydrogen plants and many currently carbon intensive industrial users in the regions converting to hydrogen (ibid).

HyNet's plans are ambitious, and in the long-term include hydrogen/gas blending facilities, green hydrogen using wind generated electricity, hydrogen powered vehicles. More practically, the current focus is on the development of the blue hydrogen production plant at Stanlow, carbon transport pipeline and undersea storage in Liverpool Bay, with additional and linked blue hydrogen carbon capture and storage plants.

Key players

- Essar (India) and multinational energy, mining and construction company owns the Stanlow refinery
- Vertex Hydrogen – a collaboration between Essar and Progressive Energy (UK). Vertex Hydrogen will operate the production plant at Stanlow.
- Progressive energy, a UK consultancy company
- Hanson, part of the HeidelbergCement group (Germany)
- Eni, an Italian multinational oil and gas company
- CF, a UK fertiliser manufacturer
- Cadent, the UKs largest gas distribution company.
- INOVYN, part of the UK INEOS chemical manufacturing group
- University of Chester, the academic partner leading on workforce planning and skills requirements

Economic and environmental impact

A report commissioned for HyNet finds that until 2050 the project will support on average 4,509 jobs per year in the north west and 9,043 in the UK as a whole (Amion Consulting 2019). The report also claims a cumulative GVA contribution of £14 billion for the North West and £25 billion for the UK. Alongside this, the report claims additional job and GVA gains from inward investment as a result of HyNet giving an annual total of 5,979 jobs for the North West and 11,259 for the UK. (ibid) Average annual GVA generation for the North West is assessed at £528 million and £954 million for the UK.

Importantly, these figures are derived from assumption that go beyond the HyNet site at Stanlow, and the carbon capture, transport pipeline and storage facilities, and include the possible construction of total of 14 hydrogen reforming plants and that 20 industrial users in the region convert to hydrogen as their main energy source. Our analysis in the previous chapters suggest that in many cases, conversion to hydrogen fuel will not be optimal for many types of industry when compared to other electrification and fuel change options. As with the economic projections for Tees Valley and the Humber, potential employment and economic growth contributions must been understood in the context of an economy in transition where carbon intensive activities will be scaled back, rather than as a net contribution to economy.

The economic benefits are necessarily modelled from a set of inputs. In the case of Vivid Economics' assessments of Net Zero Teesside and Net Zero Humber, their Investment Impact Model is used (Vivid Economics 2020a, 2020b). Input-output models are a recognised method of economic appraisal that provide a valuable indication of outcomes based upon certain assumptions. At the same time, it is important exercise some caution around the results based on assumptions around, for example, the scale of business investment and projected timescales for large infrastructure projects that may be influenced by for, example, political or macro-economic changes.

Importantly, as the consultancy reports themselves make clear, the employment outcomes are jobs supported and safeguarded, rather than net new jobs. That it, then benefits might be more around firms – particularly large carbon intensive industries including and perhaps especially the oil and gas industry itself – shifting to lower carbon energy sources. In this sense, the benefits might be vital in ensuring a just transition to net zero and maintaining high value employment in the parts of the north that are currently home to our highest emitting agencies. At the same time, it is important to be pragmatic in assessing the potential for technologies such as hydrogen power and carbon capture to make the north wealthier – this is about the change and adaption of already economically high value industries.

Conclusions

As with the other major hydrogen cluster projects in the North, HyNet proposes a phased approach to hydrogen development, focussed on developing blue hydrogen and CCS infrastructure initially before ramping up green hydrogen production in the decades to come. Where HyNet differs from the other major proposed hydrogen projects is the economic base it can build upon. Unlike Teesside and the Humber, HyNet will be connected to a high productivity region (Cheshire) and strong existing industrial base. Unlike Teesside where future industries would need to build up around new hydrogen development, HyNet will likely provide benefit to a range of existing industrial businesses located in its immediate vicinity. Similarly, the combination of existing infrastructure and future plans for energy generation of the North West and North Wales are a strong combination of existing and future assets that could help HyNet grow at scale.

As with the other major hydrogen clusters proposed for the North, green hydrogen is so far, much less of a feature of HyNet, at least in the short to medium term. This remains in line with other hydrogen projects across the North which take an approach where blue hydrogen seems to be prioritised in the short-term, with the production of green hydrogen implied to be more significant in the subsequent decades.

6.
NEXT STEPS FOR THE NORTH'S HYDROGEN POWERHOUSE

The UK's hydrogen economy is still in its nascent stages. Despite this, there is clear potential for hydrogen to help the UK reach its net zero objectives. This is primarily through providing alternative fuels for industrial decarbonisation, although it could also play an important role in decarbonising heavy freight and passenger transport.

To maximise the climate and economic impact of hydrogen, further clarity is needed on the precise actions that the government will take to reach its target of producing 10Gw of hydrogen fuel by 2030 (BEIS 2022a). There are environmental and economic considerations that must be assessed if the UK's future hydrogen economy is going to deliver tangible benefits. Our analysis suggests that despite higher initial costs, green hydrogen provides greater long-term certainty because it is guaranteed to be emission free and its production method complements the wider need to massively expand the UK's current renewable energy generation potential.

In the North, hydrogen clusters remain in their infancy. Despite this, the potential economic and specific job-generating benefits attached to future hydrogen production are not yet certain. While a shift to hydrogen will support existing jobs and likely create new ones, the extent to which this truly transforms the areas in which they are located will be contingent on wider factors such as giving local people the skills they need to take on new jobs. Wider investment will also be needed to grow key research institutions and businesses across the North that will be key to securing the UK's hydrogen future.

RECOMMENDATIONS

To ensure that the UK's development of hydrogen maximises both its environmental and economic impact, particularly in the context of levelling up the north of England, three sets of policy actions are needed from government. These cover the need for hydrogen to promote long-term environmental and economic certainty, the need to build the UK's wider hydrogen infrastructure and a specific need to support the north of England's wider hydrogen economy to close regional divides.

A hydrogen plan that provides environmental and economic certainty

The UK government currently has a hydrogen strategy that emphasises its ambition to scale up the UK's supply of hydrogen. It's current 10Gw target by 2030 is clearly ambitious. However, further planning needs to be done to ensure that green hydrogen is the primary source of hydrogen fuel in use by 2050. The current evidence suggests that while the current costs for producing hydrogen may be high, these costs are likely to fall significantly in the coming years. It is also important to consider that alternatives to green hydrogen, such as the use of blue hydrogen in the intervening period are not low cost. For example, a blue hydrogen pathway would also require building significant amounts of CCS infrastructure, which will also result in signficant costs to build and maintain.

We recommend that the UK government does the following.

- Prioritises the further development and expansion of green hydrogen production, with particular focus on expanding domestic renewable energy generation needed to produce more green hydrogen at scale.
- Ensure that the development of hydrogen occurs in line with an assessment of economic sectors where it is needed. Our analysis suggests that this is largely in relation to industrial decarbonisation processes. In contrast, attempting to develop hydrogen as a scalable solution for domestic heating is neither realistic or plausible based on current or future projections of the UK's hydrogen production (Webb et al 2020).
- Introduce a 'deep blue hydrogen' standard which requires all CCS technology to meet a minimum 95 per cent capture rate, as assumed by the CCC (2020a), and issues severe penalties for methane leakages. Further efforts need to be made to establish the environmental credentials of proposed blue hydrogen projects. While current evidence suggests green hydrogen is genuinely zero carbon, the extent to which blue hydrogen can be a credible part of the UK's net zero is highly dependent on on the rate of emissions captured from its production process.

Developing the UK's wider hydrogen infrastructure

The UK government's current hydrogen plans largely coincide with plans to decarbonise major industrial clusters. For this report, we have focussed on the three industrial clusters in the north of England. However, while there is a clear rationale for developing new industrial infrastructure and processes for hydrogen within the current industrial clusters, wider innovation and development of new technologies will be needed to accelerate the production of hydrogen across the UK. Across the north of England, and more widely, there are a range of research institutions and businesses who can help further develop the hydrogen economy. It is crucial that these organisations outside of clusters are also included. We recommend the UK government ensures this by doing the following.

- Expanding government investment available to support businesses and research institutions located outside of current clusters whose work can help support and develop the future hydrogen economy.
- Specific sector support to adopt hydrogen where it is needed. For example, within the manufacturing and construction sub-sectors, such as the steel industry. In the case of the steel industry, previous IPPR North analysis demonstrates that the current support on offer is not enough and that further support for early adoption should be made (Webb 2021).
- Alongside its newly appointed 'Hydrogen Champion', the government should establish a hydrogen strategy group whose membership is geographically diverse, unbiased and well informed of current hydrogen developments to help the government plan for the use of hydrogen in sectors where it is needed.

Support for the North's wider hydrogen economy

Hydrogen in the North offers potential environmental and economic benefits. Already, a significant amount of private investment is finding its way into the North's nascent hydrogen economy. To further accelerate this investment, we recommend the following.

- Central government should continue to work with its partners including the Energy Systems Catapult, UK Research and Innovation, Local Enterprise Partnerships and combined and local authorities to develop concrete plans for hydrogen development at the local level.
- Central government should create new hydrogen acceleration forum to drive hydrogen development in the North. This could pilot new innovations and coordinate investment across and between different northern regions with the aim of promoting innovation and collaboration, as opposed to competition.

- Central and local government should work together to establish a just transition framework that can help local workforces transition into new low carbon industries, such as hydrogen. This will also require significant investment in developing new low carbon industry educational courses that can be administered through local further and higher education institutions.

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